FOSSIL WOOD OF BIG BEND NATIONAL PARK, BREWSTER COUNTY, TEXAS: PART I—GEOLOGIC SETTING

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Abstract

Fossil wood was collected from the Dawson Creek area of Big Bend National Park with the intent of performing certain chemical tests on the material. The geologic formations in which the wood was found are described in this part of the report. A model based on the Flood is offered for the origin of these formations. The importance of bentonite in the preservation of the silicified wood is discussed. Applications to a catastrophic model are suggested throughout the paper.

Key Words: Javelina Formation, Aguja Formation, Bentonite, Charcoalized Wood, Silicified Wood, Catastrophism.

Introduction

While on a field trip in Big Bend National Park during the summer of 1990, George Howe, William Waisgerber, and Emmett Williams observed logs, limbs, and smaller pieces of silicified and charcoalized wood in the upper Cretaceous Gulfian Series of rocks in the western end of the Park near Study Butte, Texas. In 1991 and 1992 specimens of the various fossil woods were collected from the Dawson Creek area (29° 18'N, 103° 31'W, Terlingua, Texas quadrangle USGS topographic map) with the permission of the National Park Service in order to study the materials. The purpose of the project was to determine if radiohalos were present in any of the samples, to conduct C-14 age studies on the charcoalized woods, to ascertain the silica content of the petrified specimens and to study the structure of the woods using optical and scanning electron microscopy techniques.

Although we employ conventional geologic terminology in this paper such as Cretaceous, Paleocene, Mesozoic, etc., we do not subscribe to the standard geologic timetable.

Javelina and Aguja Formations

All samples were collected either from the lower Javelina or from the upper Aguja formations (Gulfian Series). Maxwell, et al. (1967, p. 1) stated that "Gulfian rocks are flaggy, argillaceous limestone, chalk, marl, clay, bentonitic clay, and sandstone." A brief description of the lithology and standard stratigraphic placement of the Javelina and Aguja formations is given in Table I. A complete description of several sections of these formations in Big Bend National Park can be found in Maxwell, et al., 1967. Also sections of the Aguja formation are mapped and discussed in Hopkins, 1965. For brief descriptions of the Aguja and Javelina formations outside the National Park, see Yates and Thompson (1959, pp. 14-16); Moon (1963, pp. 170-173).

A suggested origin for these formations is presented in Appendix I and possible correlation with other Cretaceous formations is given in Appendix II for interested readers. Concerning these two formations in the Dawson Creek area (where we collected our samples), Maxwell, et al. made the following observation, "Although the base is covered, nearby exposures indicate that there is no marked lithologic difference between the basal Javelina and the upper Aguja" (p. 94). In 1972, Paleocene mammal bones were found in the upper part of the Javelina formation (Pause and Spears, 1986, p. 58), thus it is now considered "late Cretaceous—Paleocene" by some investigators. For instance Rigsby (1986, p. 111) and Schiebout (1986, p. 129) showed stratigraphic charts with the upper Javelina formation in the Paleocene. However some recent publications (Nelson, 1992, p. 6; Spearing, 1991, p. 295) still show the complete Javelina formation as upper Cretaceous.

Since all of the permineralized (petrified) and charcoalized wood samples were found in bentonitic clay deposits (Figures 1 and 2), we will concentrate our discussion on the importance of these mounds in the preservation and petrification of wood.

The Importance of Bentonite in the Silicification of Wood

Bentonite is defined by Ross, Miser, and Stephenson (1929, p. 185) as:

> . . . a rock composed predominantly of clay and formed by the alteration and devitrification of glassy volcanic material usually a tuff. It generally contains differing proportions of igneous-rock phenocrysts and admixed detrital debris. Most bentonites contain montmorillonite* as their characteristic clay mineral . . .

When it erodes, bentonite forms badlands which cannot be farmed. It has the property of absorbing water and swelling considerably so that water does not penetrate deeply into the clay.

Murata (1940, p. 586) noted that bentonite is the decomposition product of water laid volcanic ash which is rich in silica (SiO_2). During the alteration of volcanic ash by water, large amounts of SiO_2 are liberated (p. 587). Then he claimed:

> Therefore it seems reasonable to believe that the chance for woody materials to become silicified would be greatly enhanced if they were buried, under conditions of minimum decay, in volcanic

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*Kingery (1960, p. 18) gives the composition of montmorillonite as

$$\left(Al_{1.67}\begin{matrix}Na_{0.33}\\Mg_{0.33}\end{matrix}\right)(Si_2O_5)_2(OH)_2$$

The mineral has various applications in ceramic industries.

Table I. Sequence of Strata in Big Bend National Park.

Era	Period	Epoch		Group (Rock Units)	Formation (Rock Units)	Thickness (feet) (Rock Units)	Lithology (Rock Units)
CENOZOIC	QUATERNARY	RECENT and PLEISTOCENE			Alluvial deposits	100-500	Clay, silt, sandstone, and conglomerate
	TERTIARY	OLIGOCENE or YOUNGER		Big Bend Park	South Rim Formation	1,000-1,500	Thick ledge-forming lava flows exposed high in Chisos Mountains, ash beds, tuff, flow breccia, irregularly bedded sandstone and conglomerate
		EOCENE	Upper		Chisos Formation	1,500-2,600	Indurated tuff interbedded with clay, mudstone, tuffaceous sandstone, ash beds, lavas, sandstone, and conglomerate
			Middle		Canoe Formation	1,170	Base is a massive yellow cross-bedded ledge-forming sandstone overlain by tuff, mudstone, tuffaceous sandstone, indurated tuff, and lavas
			Lower	Tornillo	Hannold Hill Formation	356-770	Soft, gray, and yellowish-gray conglomeratic sandstone and varicolored and mottled clay
		PALEOCENE			Black Peaks Formation	850	Varicolored clay interbedded with ledge-forming cross-bedded, yellow, buff, and gray sandstone and lenses of conglomerate
MESOZOIC	CRETACEOUS	GULFIAN			Javelina Formation	350-850	Gray, dull green, blue, red, yellow, purple, brown, black, and white clay, with thin layers of sandstone. Clay commonly bentonitic; contains fossil wood and dinosaur bones
					Aguja Formation	800-1,300	Upper part, 300-700 feet thick. Nonmarine dark-gray carbonaceous clay and some silt and layers of coal interbedded with brown and yellowish-brown sandstone. Contains fossil wood and dinosaur bones Lower part, 500-706 feet thick. Marine sandstone and clay, a shelly sandstone generally present at the base
				Terlingua	Pen Formation	220-600	Dark grayish-blue gypsiferous marl and clay that weathers yellow, with concretionary limestone and layers of calcareous sandstone.
					BOQUILLAS FORMATION: San Vicente Member	330-400	Gray and bluish-gray chalk and gray to buff argillaceous flaggy limestone
					BOQUILLAS FORMATION: Ernst Member	475	Gray, buff, and yellowish-brown flaggy limestone interbedded with gray and buff marl
		COMANCHEAN			Buda Limestone	100	Whitish, dense, brittle limestone and nodular limestone interbedded with marl
					Del Rio Clay	1-125	Light gray and yellow clay, clay-shale, and thin-bedded limestone
					Santa Elena Limestone	750-850	Mostly massive, thick-bedded, dense, cherty, ledge-forming limestone, with thin-bedded marly limestone near base
					Sue Peaks Formation	75	Shale, marl, and thin marly, nodular limestone ledges
					Del Carmen Limestone	350-450	Massive, heavy-bedded, dense, cherty, ledge-forming limestone
					Telephone Canyon Formation	40-130	Thin, nodular, marly limestone and marl
					Maxon Sandstone	10	Medium-grained, calcareous sandstone
					Glen Rose Formation	600	Dense limestone interbedded with calcareous shale, erodes to form step-like benches, conglomerate and coarse sandstone at base
PALEOZOIC					Paleozoic sedimentary rocks (undifferentiated)	Unknown	Strongly folded rocks, including slightly metamorphosed shale, chert, novaculite, and limestone
					Metamorphic rocks	Unknown	Fine-grained schist, metaquartzite, phyllite, and marble

Figure 1a. Collecting area for charcoalized and silicified wood samples. This view is looking northwest from the Badlands Overlook at Painted Desert Junction. Note bentonitic clay mounds in the center of the photograph where samples were obtained. Maverick Mountain is in the background. Note the extensive erosion evident along the "badlands" (Dawson Creek, north of Park Road). Photograph taken in March 1991.

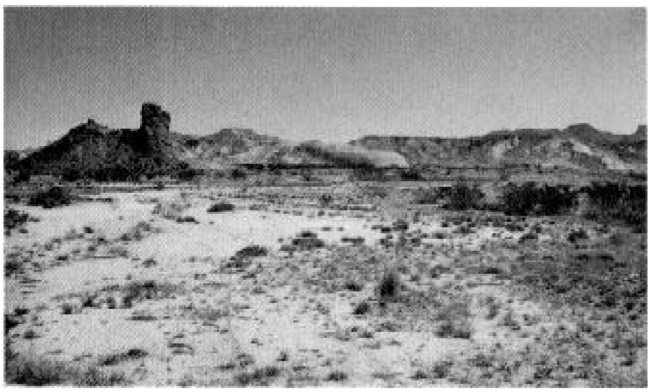

Figure 1b. Same area as seen in Figure 1a except viewed from Park road looking north. The closest bentonitic mound is in the center of the photograph to the right of the long "column." Maverick Mountain is to the left front, not in the photograph. This photograph was taken in March 1992. Many of the perminerlized logs that were exposed in 1991 were missing from the collecting site in 1992. Again note the evident erosion.

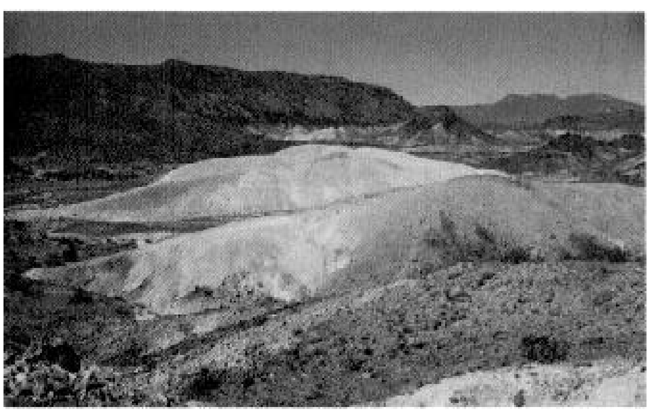

Figure 1c. Bentonitic clay mounds south of Park road (looking northwest) from where some fossil wood samples were collected. Maverick Mountain can be seen at the left rear (horizon) of the photograph. Note the similarity of appearance between the clay mounds in a-c and the bentonitic clay mounds shown in Figure 8 of Rosnau, et al., 1989a, p. 46. Interestingly this area in Big Bend is within one mile of a road junction formally known as the Painted Desert Junction.

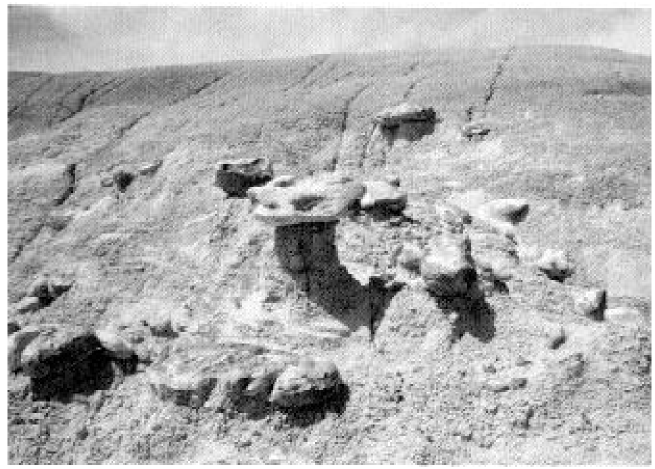

Figure 2a. Concretions in bentonitic clay mounds shown in Figure lc. Rosnau, et al. (1989b) observed numerous similar appearing concretions in the Kayenta of Arizona. See Figure 29, page 92 of that article.

Figure 2b. A small and a large concretion in same area (Figure 1c). Hammer rests on the two concretions.

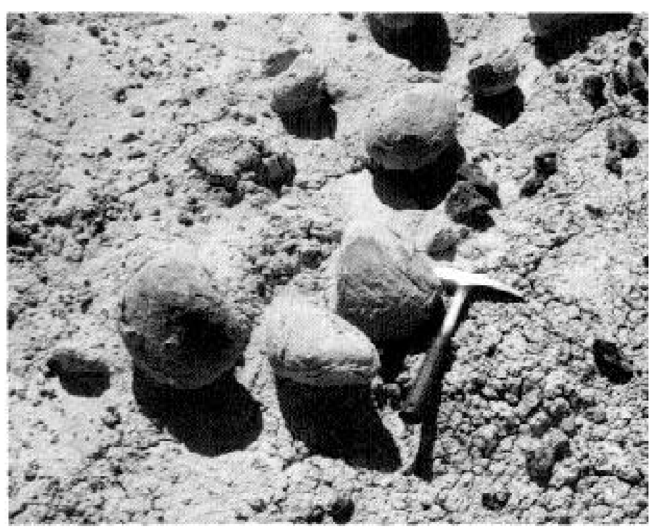

Figure 2c. Several smaller concretions.

ash or in sediments rich in volcanic ash. Actually a great many occurrences of silicified wood in volcanic ash are known. Silicification by percolating waters is also conceivable in a porous stratum, like coarse sandstone, that is under or overlain by a deposit of volcanic ash (p. 589).

Considerable Volcanic Activity in the Western U.S. in the Past

Clark (1966), Peters (1973, p. 89), and Rosnau et al. (1989b, pp. 85-86) discussed the presence of bentonite in the western United States from the perspective of catastrophism. Many bentonitic formations are indicative of the vast extent of volcanic activity in the past.

Decker and Decker (1981, p. 116) noted:

> Huge deposits of pyroclastic flows that cover thousands of square kilometers and are tens to hundreds of meters thick exist in Japan, New Zealand, Central America, the *western United States,* and many other volcanic regions of the world. Some of these deposits give every indication that they were poured out in a single enormous eruption that would dwarf Krakatau. The volume in these deposits is on the order of 100 to 1000 cubic kilometers compared to the 18 cubic kilometers of Krakatau (emphasis ours).

Kauffman (1977, p. 87) in discussing interior western United States bentonite formations, particularly the volcanic eruptions that released the ash, stated that "These ashes settled widely over the Cretaceous seaway in a short period of time, . . ." Some of the bentonite deposits extend outward for over a thousand miles from the source areas and are used as marker beds. Again immense, widespread volcanic activity in the past is consistent with a catastrophist interpretation.*

In relation to this volcanic activity, Hopkins (1965, p. 107) commented concerning the Aguja formation as follows:

> The large percentage of bentonitic claystones in the upper part of the [Aguja] formation suggests that at times the streams were choked with mud, or that the ash falls in the source area increased in later Aguja time. As previously mentioned, the red color of many of the Aguja claystones suggests a change to a humid climate.

This volcanic activity, particularly the ash falls, produced conditions that were favorable for the silicification of wood which was covered by settling volcanic material. It is possible that immediately after the Flood, the Big Bend region had a climate with abundant rainfall. See Oard, 1990 for a discussion of possible post-Flood climatic conditions, particularly in the western United States. If the woody material in the Dawson Creek area were transported to its burial site, then covered with volcanic ash and if there was ample rainfall, these conditions would have been favorable for the silicification of buried plants.

Summary

The formations in which the fossil wood was found were described briefly. Hopefully, other creationist studies on deposits of petrified wood can be compared with this setting and a common catastrophic mechanism or mechanisms suggested. The relationship of bentonite to silicified wood deposits has been discussed. Extensive post-Flood volcanic activity has been suggested as a source for the tuff needed to form bentonite. Abundant rainfall immediately after the Flood could have encouraged silicification of the buried wood. This possibility will be explored in Part II of this series. The chemistry of the fossil wood will be presented in Part III and microscopic characteristics of the material will be discussed in Part IV.

Appendix I
Suggested Origin of Javelina and Aguja Formations

Maxwell, et al., 1967, p. 92 state that:

> The Javelina Formation has all the characteristics of a continental deposit. Lack of sorting and lack of structure in the clay suggest deposition from suspension in lakes whose currents were intermittent and local. Periodic oscillations drained or shifted the water bodies and caused channeling . . .

Also they (p. 81) consider that "The nonmarine Aguja is continental detritus, lacustrine and lagoonal . . ." Hopkins (1965, p. ii) noted that ". . . mottled maroon and green claystones, limestone-pebble conglomerates, and sandstone beds and channel-fillings in the upper part of the [Aguja] formation suggest deposition in coastal river flood plains." He explained (p. 1):

> The [entire] Aguja formation in Big Bend National Park, Texas, furnishes a revealing record of shifts in the paralic environments of deposition concomitant with the withdrawal of the western interior sea from the area during late Cretaceous time.

Again Hopkins (p. 109) stated:

> The lower Aguja formation records a possible beach environment and the various sub-environments associated with tidal flats. The middle part of the formation records estuarine, lagoonal, and swamp environments, and the upper part, a coastal-plain fluvial environment.

Likewise he noted:

> The upper part of the Aguja formation contains fewer features that are diagnostic of specific environments than are found in the lower part. It does, however, contain many features that are suggestive of deposits of low gradient streams and estuaries.
>
> The presence of non-marine fossils and the absence of marine forms argues in favor of a fluvial environment of deposition. The fresh water gastropod *Campeloma vetulum* (?) dinosaur remains, dinosaur tracks, and abundant petrified wood and fossil logs have already been mentioned . . .

*Camp (1930) in discussing the Chinle formation (Jurassic) in Arizona. which contains considerable bentonitic clay, made the following observations which could be interpreted within a catastrophist framework:

> Occurrences of fossil wood and bone in the Chinle are so distributed that they might be taken to indicate periods of cataclysmic extinction. From the presence of great volcanic ash deposits and the frequent occurrence of pure charcoal lumps and charcoal encrusted logs in these deposits, it would seem at first thought that the bone beds and fossil forests may have been due to sudden destruction of life by volcanic outbursts, accompanied by fire and flood (p. 8).

> The lithology of the upper part of the Aguja formation is predominantly silty claystone. These rocks may have been laid down as overbank deposits . . .
>
> Other sedimentary structures, such as trough-type cross-bedding, fit a fluvial-estuarine environment, but are present in other environments as well. The red and green color of upper Aguja claystones are also characteristic of continental deposits.
>
> Although there is no positive proof of fluvial estuarine deposits in the upper part of the Aguja formation, the agreement of all evidence argues strongly for such an interpretation (pp. 101-103).

Maxwell (1968, p. 16) showed the extent of the "Mesozoic Sea" in North America (Figure 3). Also see Williams, et al., 1992, p. 141. Lonsdale, et al., 1955, p. 40 noted that "As the Aguja sea oscillated back and forth across the Big Bend area it left a record of marine, near-shore, estuarine, and continental deposits."

Then they postulated that:

> The coal beds at the base of the first Aguja sand indicate a period of continental deposition marking a withdrawal and transgression of marine waters. The basal part of the Aguja is characterized by zones of marine fossils with oysters, gastropods, clams and ammonites (p. 39).

Hopkins (1965) speculated that:

> . . . the Aguja is a regressive sequence with records of some very minor transgressions, and that there was no significant break in sedimentation during deposition of the Terlingua and Aguja formations (p. 10)

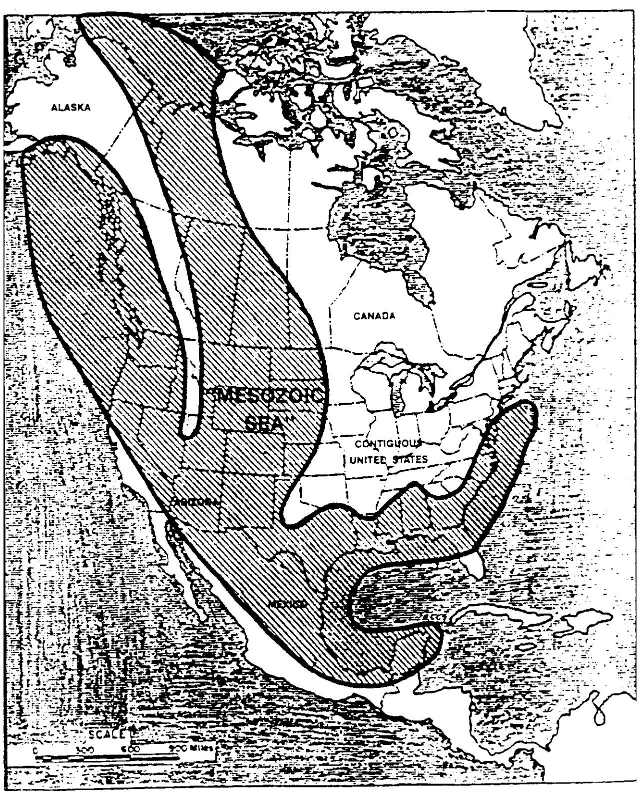

Figure 3. Map of North America showing the extent of the "Mesozoic Sea." Drawing by Martha Smith.

More recently Lehman (1984) discussed the fluvial sedimentology of the Aguja and Javelina formations and claimed:

> Late Campanian and Maastrichtian fluvial sediments of west Texas and northern Mexico were deposited following the final regression of the western interior seaway . . .

He felt that there ". . . were four or five successive episodes of re-occupation and incision" during late Cretaceous times. "Forestation and soil formation as well as local pond deposition, occurred during periods of abandonment." He also discussed possible climate changes during this postulated time interval. Lehman (1985) discussed the deposition of coal and lignite in the upper Cretaceous Aguja formation and related this deposition to the transgression-regression cycles of the "Cretaceous Sea" as proposed by Kauffman (1977) for the western United States interior Cretaceous basin. See Figure 4 for a visual model of sedimentation possibilities during a transgressive-regressive cycle.

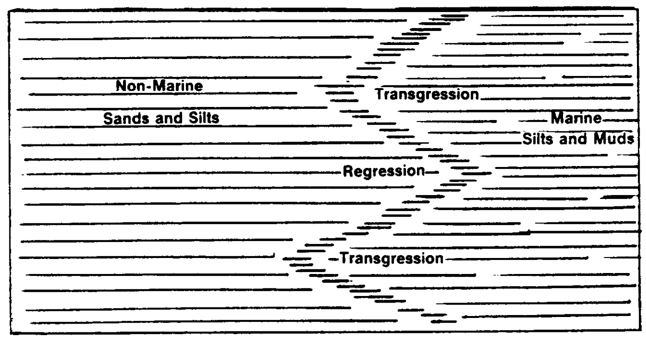

Figure 4. Idealized representation of the facies of the depositional sequence where continental and marine sediments interfinger as a result of transgressions and regressions of the sealevel at a shoreline (after Press and Siever, 1986, p. 313).

We propose a tentative, very speculative model for the deposition of the Javelina and Aguja formations based on a Flood model. Possibly as the Flood receded from the western United States, considerable water from the west Texas region flowed into and through the Big Bend area toward the Gulf of Mexico. (For a sketch of events from a uniformitarian perspective, see Moore, 1989.) The lower Aguja was one of the last sediments deposited under marine (Flood) conditions. The recession of water was almost complete in "lower Aguja times." Also inland, possibly many fresh-water lakes existed and rivers flowed toward the retreating Flood water as a postulated high precipitation climate could have provided ample surface water to erode recent deposits. Flowing fresh water, laden with erosional debris, moving generally toward the southeast began to deposit the upper Aguja formation.

During the withdrawal of the marine water and during the inland post-Flood erosive process, considerable tectonic activity was affecting the Big Bend country as the crust of the earth adjusted to the removal of water. (The Ouachita, Laramide, and Basin and Range orogenies were active in Big Bend.) With this crustal movement, there might have been transgressions of the marine water during deposition of the Aguja causing interfingering of the marine and continental sediments along the shifting shoreline. The uplift of a land mass offshore in the marine water possibly could have caused retreating Flood water to surge toward the shore. Also a local subsidence along the shore could have caused a transgression of marine water. Later, regression of the water would continue with the deposition of "continental material."

Evidence of considerable volcanic activity, similar to what Austin studied in the John Day Country of Oregon (Nevins, 1974), can be observed in Big Bend. (See Price and Henry, 1988; Henry, et al., 1989; Henry and Price, 1989; Moore, 1989; Henry, et al., 1991; James and Henry, 1991.) Many ash falls could have occurred in "Javelina and Aguja times" covering various water-logged plant matter that was deposited behind the regressing water. More study and field work are necessary to elucidate or correct any details of this speculation and it is offered only as a framework for future reference. Also a more recent occurrence of the conjectured events is postulated based on the catastrophic nature of the creationist model.

Rosnau, et al. (1989b) experienced a similar geologic situation in the Kayenta of Arizona. They postulated the following catastrophic scenario:

> . . . volcanic ash may have fallen . . . to mix with existing flooded streams on broad flood plains. Ash could have been washed into the sediments by contemporaneous overflowing rains as volcanism is usually attended by rains. Altered volcanic ash (bentonitic clay) is found surrounding the previously described freshwater molluscs, *Unio* species which likely came from overflowing lakes.
>
> Living organisms could have experienced a catastrophic demise from drowning, ashfall, and poisonous gases . . . (p. 86).

Appendix II
Suggested Stratigraphic Correlations for Javelina and Aguja Formations

Lonsdale, et al. (1955, pp. 25-28) suggested the following stratigraphic correlations for the Javelina and Aguja formations in Big Bend National Park with other Cretaceous formations in the continental United States (Table II).

Later Maxwell, et al., 1967, p. 96, made the following statement concerning correlation of the Javelina formation with other Cretaceous formations.

> The Javelina Formation in Big Bend National Park may be a nonmarine equivalent of part of the Navarro Group rocks in southwest, central, and northeast Texas, but a definite correlation is not possible. The Javelina is more nearly comparable to the nonmarine Escondido Formation of Navarro age in the Rio Grande Embayment (Maverick County) . . . *Alamosaurus* sp. bones were collected . . . from the Javelina and support a Maestrichtian age. *Alamosaurus* has also been found in the Hell Creek Formation of late Cretaceous age in Petroleum County, Montana.

Concerning the Aguja formation, Maxwell, et al., 1967, p. 97, suggested correlation as follows:

San Juan Basin New Mexico — Ojo Alamo sandstone
Lower Aguja formation correlations
Bofecillos Mountains — Boquillas formation
Buck Hill, Agua Fria, and Tascotal Mesa Quadrangles — Boquillas formation
Barrilla Mountains — Taylor Group

Another correlation of the two formations with other Cretaceous strata is given below (Maxwell, et al., 1967, p. 30) in Table III.

Table II. Regional Correlation of Javelina and Aguja Formations (after Lonsdale et. al., 1955).

Big Bend National Park Area	Reference Sequence for Western Interior	Petroleum County Montana	Southwest Texas	Northwest Texas	Northwest Louisiana
			Escondido	Kemp Clay	Arkadelphia Chalk and Marl
Javelina Formation*	Fox Hills Sandstone	Hell Creek Formation	Olmos	Corsicana Marl	
			Upper San Miguel	Nacatoch Sandstone	Nacatoch Sandstone
	Pierre Shale	Bearpaw Shale			
		Judith River Formation	Lower San Miguel	Neylandville Marl	Saratoga Chalk
Aguja Formation			Anacacho Limestone	Pecan Gap Chalk	Marlbrook Marl
	Eagle Sandstone			Wolf City Sandstone	Annona Chalk (restricted)
					Ozan Buckrange Sandstone

*Referred to as Tornillo (restricted).

Table III. Correlation of Javelina and Aguja Formations (after Maxwell et al., 1967).

Big Bend National Park Area	Reference Sequence for Western Interior	Rio Grande Embayment of Southwest Texas	Central Texas	Northwest Texas
Javelina Formation	Fox Hills Sandstone	Escondido Formation	Kemp Clay	Kemp Clay
		Olmos Formation	Corsicana Marl	Corsicana Marl
		Upper San Miguel Formation		Nacatoch Sandstone
Upper Aguja Formation	Pierre Shale	Lower San Miguel Formation	Bergstrom Formation	Neylandville Marl
		Anacacho Limestone	Pecan Gap Chalk and Clay	Pecan Group Chalk
				Wolfe City Sandstone
Lower Aguja Formation		Upson Clay	Sprinkle Formation	Lower Taylor Formation
	Eagle Sandstone ⇩			⇩ Gober Chalk

⇩Eagle Sandstone and Gober Chalk are correlated with lower formations also.

Hopkins (1965, p. 10), in evaluating the Aguja formation, suggested that it "fits roughly into the stratigraphic interval represented in central Texas by the Taylor group . . ." Also he postulated correlation of the Aguja with the Judith River formation of Montana and the Belly River formation of Alberta as did Maxwell, et al., 1967, p. 87. Hopkins (p. 102) speculated that the Aguja may correlate with upper Cretaceous formations in the San Juan Basin of New Mexico. Lehman (1985; 1986) noted that exposures of the Javelina and Aguja formations in Presidio, Hudspeth and Jeff Davis counties, Texas as well as in adjacent Mexico have been assigned to the El Picacho and San Carlos formations respectively.

Glossary

Argillaceous — containing clay

Devitrification — to change the properties of glassy material to those of nonglassy substance

Estuarine — formed in an estuary (where a river current meets the sea tide)

Fluvial — pertaining to a river such as deposits produced by a river

Lacustrine — pertaining to a lake such as strata formed at the bottom of a lake

Lithology — description of rocks, generally megascopic

Marker Bed — distinctive stratum that is fairly easily identifiable and can be traced over wide area (useful in correlations) or a stratum chosen as a reference for structure mapping

Paralic — pertaining to the seacoast, often in geology referring to interfingered marine and continental deposits

Phenocryst — a crystal significantly larger than the crystals of surrounding minerals and ordinarily conspicuous

Pyroclastic — fragmented rock of igneous origin such as ash, tuff, etc.

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